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RESEARCH MEMORANDUM

JUN - 1947

WIND-TUNNEL INVESTIGATION OF BOMB-BAY CONFIGURATIONS INTENDED

TO MINIMIZE THE TUMBLING OF LIGHT-WEIGHT BOMBS

By

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

WIND-TUNNEL INVESTIGATION OF BOMB-BAY CONFIGURATIONS INTENDED

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SUMMARY

An investigation has been conducted in the Langley 300 MPH 7- by 10-foot tunnel to determine what modifications could be made to conventional bomb bays to reduce the tumbling difficulties experienced with light-weight bombs. The investigation consisted mainly of photographic studies of the trajectory and attitude of $\frac{1}{10}$-scale dynamic models of 100-pound bombs as they dropped from various bomb-bay configurations together with tuft studies of the flow in and around these bomb-bay configurations.

The investigation indicated that there is a definite region of reversed flow inside the bomb bay which must be weakened or destroyed if good drops are to be obtained. The most satisfactory configuration tested consisted of a bomb bay divided into compartments in conjunction with a deflector plate ahead of the bomb bay. Satisfactory bomb drops were also obtained by opening only a small hole in the bomb bay directly below the bomb to be dropped. On the basis of the satisfactory drops obtained with spherical bombs, it appears that bombs whose drag changes least with attitude will give the most satisfactory drops.

INTRODUCTION

An investigation has been conducted in the Langley 300 MPH 7- by 10-foot tunnel to determine what modifications to conventional bomb-bay designs are necessary to insure satisfactory drops with light-weight (100 lb) bombs. It has been reported that light-weight bombs frequently described erratic initial trajectories when dropped at relatively high bombing speeds (of the order of 300 miles per hour and greater). This behavior, apart from precluding accurate bombing, sometimes resulted in the bombs hitting each other and causing explosions.

The present investigation consisted of a photographic study of the trajectories described by small model bombs as they were released from a simulated bomb bay in a fuselage model. The tests were conducted at two tunnel speeds and the effects of various deflectors, separators, door arrangements, and bomb-bay modifications were investigated. In addition, tuft studies were made of the flow in and around the bomb bay and static pressure fluctuations were measured at two points in the bomb bay for some of the bomb-bay configurations investigated.

SYMBOLS

C_D drag coefficient $\left(\dfrac{Drag}{qS}\right)$

S wing area, 11.65 square feet

q dynamic pressure $\left(\dfrac{1}{2}\rho V^2\right)$ pounds per square foot

ρ density of air, slugs per cubic foot

V velocity of air, feet per second

MODEL AND APPARATUS

The tests were conducted in the Langley 300 MPH 7- by 10-foot tunnel.

The model used in this investigation consisted of a fuselage supported by a rectangular wing. The fuselage did not represent any particular airplane but was merely a fairing around the bomb bay. A photograph of the model mounted in the Langley 300 MPH 7- by 10-foot tunnel is presented in figure 1 and the principal dimensions of the model are presented in figure 2. The basic bomb-bay modifications investigated are presented in figure 3. These modifications were made by inserting wooden blocks in the original configuration. The various deflectors, separators, and door arrangements investigated are presented in figures 4, 5, and 6, respectively.

For the bomb-drop tests $\frac{1}{10}$-scale dynamically similar models of a 100-pound general-purpose bomb (fig. 7) were dropped from the bomb bay

into a net which can be seen in figure 1. Preliminary tuft studies
indicate that this net did not appreciably affect the flow within
about 18 inches of the model. The relations of reference 1 were used to
compute the weight and moments of inertia of the $\frac{1}{10}$-scale model bombs
which were ballasted with lead to bring these quantities and the center
of gravity to the correct magnitude and position. The bombs were held
in the bomb bay by small electro-magnetic bomb shackles (fig. 8)
operated from a 12-volt storage battery. The bombs were released by
breaking the magnetic circuit and the bomb trajectories were recorded
by a still camera in conjunction with two Strobolux lights. The
Strobolux lights were set to flash 2400 times per minute so the time
between two bomb images on the picture is one-fortieth of a second.

The fluctuation of the static pressures within the bomb bay
were measured at two points in the bomb bay. These orifices can be
seen on figure 8 and their locations are given in figure 2. The time
history of the pressure fluctuations was picked up by an electrical
pressure transmitter and recorded by an NACA film recorder.

TESTS

In order to have the trajectories of the $\frac{1}{10}$-scale model bombs
simulate those of the full-scale bombs, it is necessary that the model
bombs be dropped at tunnel speeds which correspond to the full-scale
flight speed according to the relations of reference 1. For the $\frac{1}{10}$-scale
bombs used in these tests the relationship between the tunnel speed,
equivalent flight speed, and the scale of the bombs is given by:

$$\text{Velocity (flight)} = \frac{\text{Velocity (tunnel)}}{\sqrt{N}}$$

$$= 3.16 \text{ Velocity (tunnel)}$$

where

$$N = \text{Scale of bomb } (1/10)$$

The majority of the tests were conducted at a tunnel speed of
142 miles per hour, corresponding to a flight velocity of 450 miles
per hour. Some of the tests, however, were made at a tunnel speed of
47.5 miles per hour, corresponding to a flight velocity of 150 miles
per hour.

The angle of attack of the fuselage was held constant at 0° for all tests. The different configurations tested are tabulated in table I. For most configurations two bombs were dropped simultaneously; one from the front shackle and one from the rear and usually three or four drops were made from each configuration. Typical photographic time histories of some of the bomb drops are presented in figure 9. Unless otherwise stated, all the drops were made at an equivalent flight speed of 450 miles per hour. In these pictures the rebound of the bomb from the net can be seen and should not be confused with the actual drop.

RESULTS AND DISCUSSION

The results of the drop tests for each configuration investigated are summarized in figure 10. For each configuration presented, the direction and nature of the air flow within the bomb bay is depicted as well as the bomb trajectories. The symbols and conventions employed in the presentation are defined in one of the two sketches preceding configuration 1. The other sketch presents the ideal trajectory of a bomb as calculated on the assumption that the bomb maintains zero angle of attack as it leaves the bomb bay. For these computations a bomb drag coefficient of 0.195 was assumed, corresponding to the measured minimum drag coefficient of a 300-pound bomb (reference 2). The "ideal" trajectory can be used effectively in judging the merits of the various configurations investigated. Unless otherwise stated, all the results presented in figure 10 were obtained at an equivalent flight speed of 450 miles per hour.

Configuration 1 presents a more or less conventional bomb-bay configuration. The erratic behavior of the bombs dropped from the rear of the bomb bay is immediately evident. However, reducing the simulated airspeed from 450 to 150 miles per hour reduced the tumbling and divergence to the point where consistently good drops could be secured from either bomb position. The improvement with reduced airspeed has also been noticed in flight. Lowering the bomb shackle altered the behavior but it was still not satisfactory.

It can be seen that for almost all configurations for which tuft studies were made, there is a definite flow reversal which causes the bombs to tumble and which therefore must be destroyed or weakened in order to obtain consistently good drops. Opening only a small hole in the bomb bay for the bombs to drop through resulted in some fairly satisfactory drops (configuration 3). This solution, however, would necessitate making the doors of the bomb bay in small sections and only opening those sections under the bombs to be dropped and would possess the objectionable feature of precluding salvo-type bombing.

Attaching deflectors to the fuselage ahead of the bomb bay with no other alteration did not improve conditions appreciably. It can be seen that in many configurations the bombs were actually carried forward from their release position while still inside the bomb bay and then blown back as they emerged.

One modification that was tried in an attempt to improve the dropping characteristics of light-weight bombs was to fair out the rear end of the bomb bay to weaken the reverse flow. This alteration (designs C and D) did not in itself materially help matters. However, attaching a perforated deflector 6 inches ahead of the bomb bay and extending the doors forward to the deflector in combination with bomb-bay design "C" (configuration 35) seemed to have some merit. In the interest of expediency this modification was accomplished by inserting a block of the proper shape in the rear of the bomb bay rather than alter the model itself. It will be noted that with this arrangement the bomb bay is considerably shortened but it was felt that this would have a negligible effect on the qualitative results obtained.

One of the most effective configurations investigated consisted of dividing the bomb bay into small cells, each cell large enough for one vertical string of bombs. This modification, in conjunction with a perforated deflector (configuration 11), resulted in the most satisfactory drops. The tests indicate that these cells should have solid walls to be most effective. Although the doors were off in this configuration, tests of other configurations with and without doors indicate that the doors should have little effect.

Any bomb possessing a considerable amount of stability will tumble somewhat when immersed in a strong turbulent flow. Large changes in the attitude of the bomb associated with this tumbling will cause large variations in drag which will greatly affect the path of the bomb. It is of interest to note that spherical bombs drop satisfactorily from either of the bomb positions (configuration 20). The spherical bombs used for these tests were solid steel balls and were about twice as heavy as the $\frac{1}{10}$-scale model bombs but it is believed that the fact that the drag of a sphere does not change with its attitude is the factor most responsible for the excellent drops obtained.

For some of the configurations, records were made of the fluctuations of the static pressure at two points in the bomb bay (fig. 2) and the results are presented in table I. The installation of cells in the bomb bay (configuration 10) considerably reduced the amplitude of these fluctuations, especially in the rear of the bomb bay.

Drag measurements were also made on some of the configurations and the drag coefficients are presented in table I. These drag coefficients

are based on the wing area of 11.65 square feet; the drag coefficient
of the model with the bomb bay closed is 0.035 and the drag coefficient
of the wing alone is 0.028. Attaching deflectors ahead of the bomb
bay materially increased the drag. However, a wedge-shaped deflector
gave the smallest increase in drag.

CONCLUSIONS

On the basis of wind-tunnel tests of various bomb-bay configu-
rations, the following conclusions are indicated:

1. There was a definite region of reversed flow inside the bomb
bay of conventional design and it was this reversed flow which caused
the light-weight bombs to tumble as they dropped.

2. Satisfactory drops were obtained by opening only a small door
in the bomb bay for the bombs to drop through instead of opening the
entire bottom of the bomb bay.

3. The most satisfactory configuration tested consisted of a
bomb bay divided into compartments in conjunction with a deflector
plate ahead of the bomb bay.

4. The satisfactory results obtained with spherical bombs
indicate that bombs whose drag changes least with attitude will give
the most satisfactory drops.

Langley Memorial Aeronautical Laboratory
        National Advisory Committee for Aeronautics
                Langley Field, Va.

REFERENCES

1. Scherberg, Max, and Phode, R. V.: Mass Distribution and Performance
        of Free Flight Models. NACA TN No. 268, 1927.

2. Baals, Donald D., and Smith, Norman F.: Aerodynamic Tests of an
        M-31 Bomb in the 8-Foot High-Speed Tunnel. NACA MR, Aug. 25,
        1942.

TABLE I. - TABLE OF BOMB-BAY CONFIGURATIONS TESTED AND RESULTS OBTAINED

Configu-ration no.	Configuration				Drag[1] coef-ficient C_D	Static pressure fluctuation in bomb bay			
	Bomb bay (fig. 3)	Deflector (fig. 4)	Separators (fig. 5)	Doors (fig. 6)		Front orifice		Rear orifice	
						Amp.[2]	f[3]	Amp.[2]	f[3]
1	A	-	-	A	0.044	4.2	28	17.5	42
2	A	-	-	Off	0.044	6.0	19		
3	A	-	-	D					
4	A	-	A	A	0.045	5.2		12.0	46
5	A	C-0	A	A					
6	A	-	B	A	0.046	4.5	21		
7	A	A-6	B	A					
8	A	B-6	B	A					
9	A	C-0	B	A					
10	A	-	C	Off	0.043	3.2		9.3	49
11	A	B-0	C	Off					
12	A	-	D	Off					
13	A	B-0	D	Off					
14	A	B-0	E	Off					
15	A	A-0	-	A					
16	A	A-3	-	A					
17	A	A-6	-	A					
18	A	A-12	-	A					
19	A	B-0	-	A	0.061	3.2		13.3	34
20	A	B-3	-	A					
21	A	B-6	-	A	0.059	4.4		18.6	36
22	A	B-6	-	Off	0.059	3.7		17.9	34
23	A	B-12	-	A					
24	A	C-0	-	A	0.055	3.8	28	21.4	32

[1]The drag coefficient of the model with the bomb bay closed is $C_D = 0.035$.
[2]The average double amplitude of the pressure fluctuation in percent of the dynamic pressure (q).
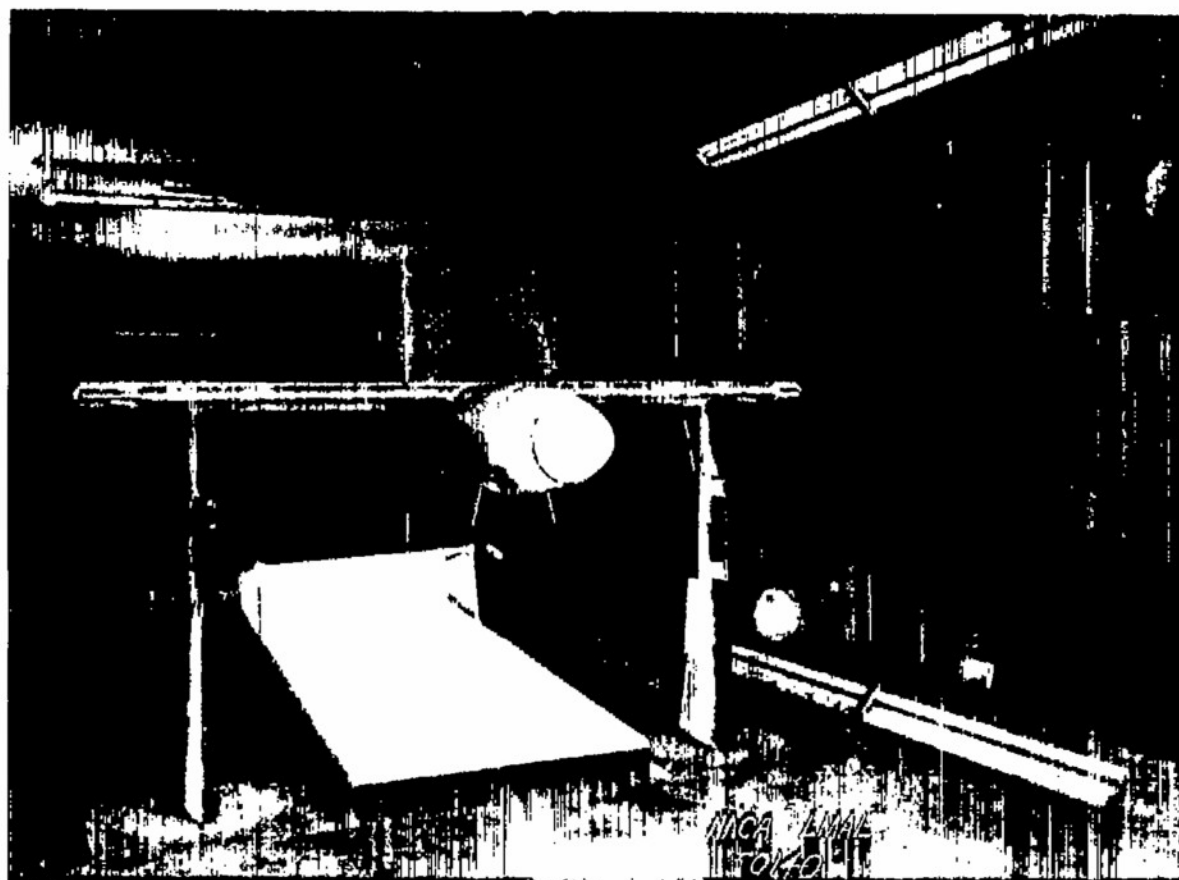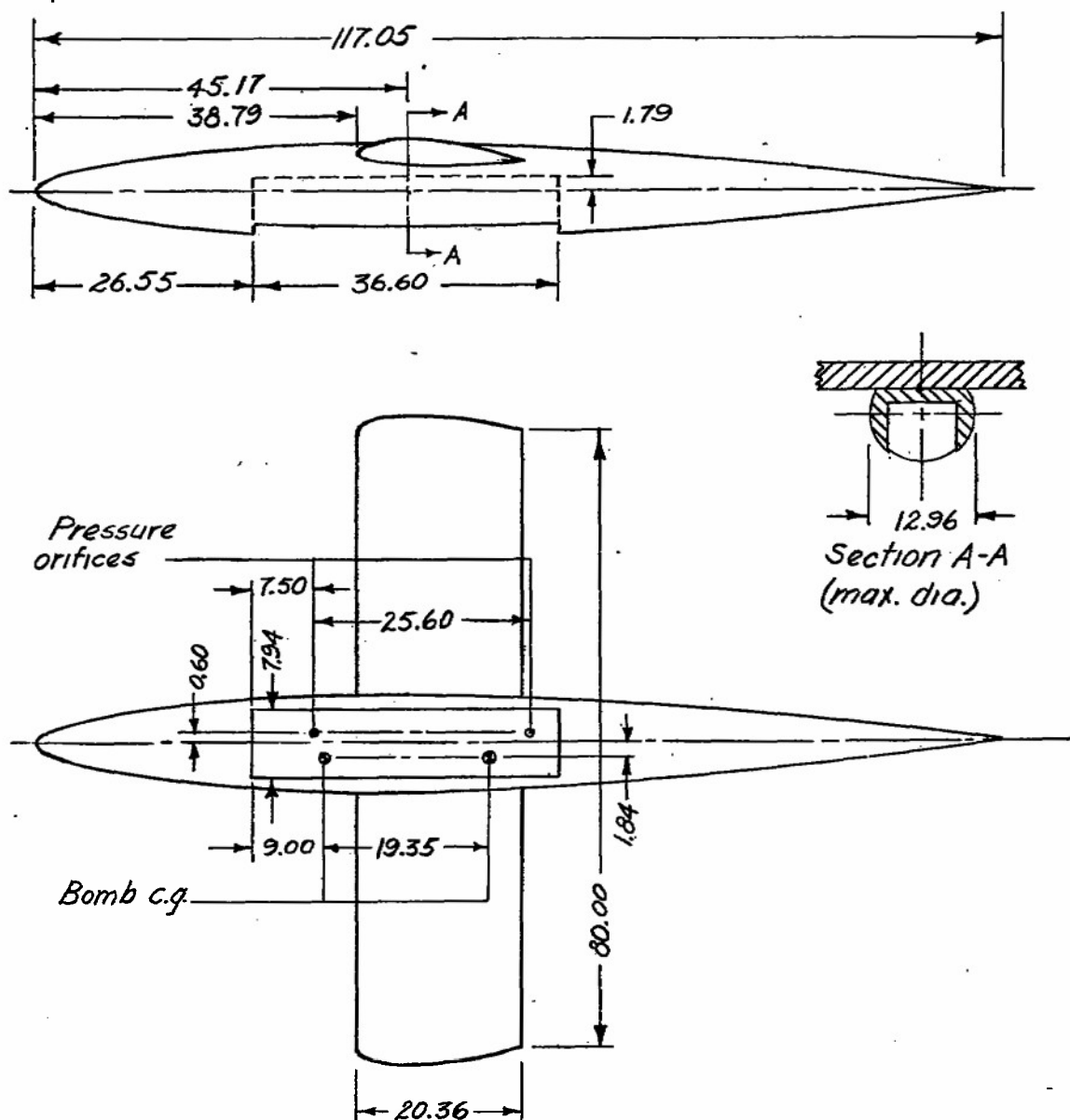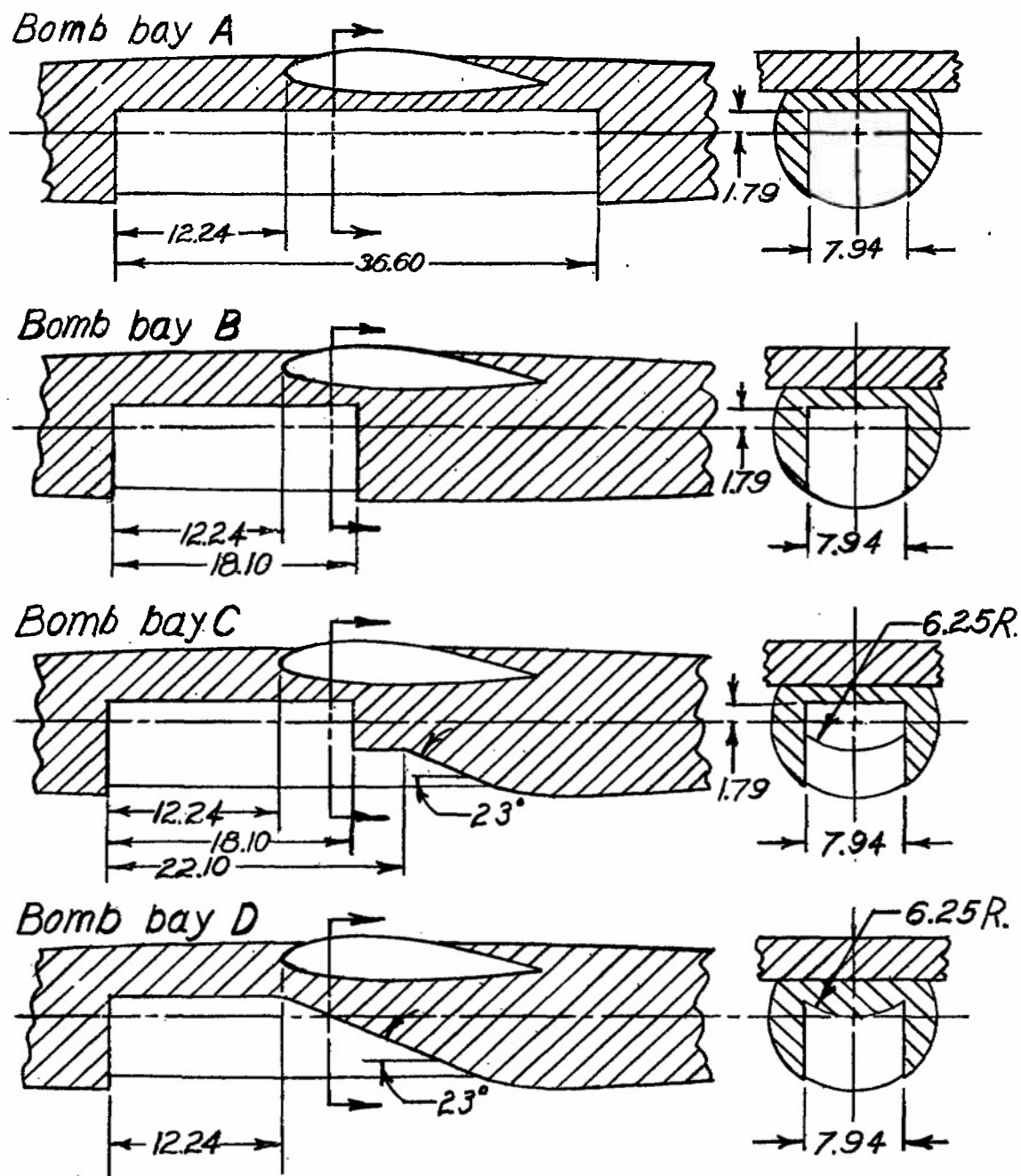[3]The frequency of the pressure fluctuation in cycles per second.

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TABLE I.- TABLE OF BOMB-BAY CONFIGURATIONS - Concluded

Configu- ration no.	Configuration Bomb bay (fig. 3)	Deflector (fig. 4)	Separators (fig. 5)	Doors (fig. 6)	Drag[1] coef- ficient C_D	Static pressure fluctuation in bomb bay Front orifice Amp.[2]	f[3]	Rear orifice Amp.[2]	f[3]
25	A	C-6	-	A	0.057	5.3			
26	A	C-6	-	Off	0.056	3.5		24.0	34
27	A	C-12	-	Off				21.4	33
28	B	-	-	B	0.043	5.5			
29	B	B-6	-	B					
30	B	B-6	-	Off					
31	C	-	-	B	0.044	2.8			
32	C	-	-	Off					
33	C	B-0	-	B					
34	C	B-6	-	B	0.054	2.8			
35	C	B-6	-	C					
36	C	B-6	-	Off	0.056	3.2			
37	C	C-0	-	B					
38	C	C-6	-	B	0.059	5.1			
39	C	C-6	-	C	0.049	6.0			
40	C	C-12	-	B					
41	D	-	-	B	0.044	2.3			
42	D	-	-	Off					
43	D	B-0	-	Off					
44	D	B-6	-	B	0.055	4.2			
45	D	C-6	-	B	0.054	5.5			
46	D	C-6	-	Off					
47	D	D	-	Off					
48	D	E	-	Off					

[1]The drag coefficient of the model with the bomb bay closed is $C_D = 0.035$.
[2]The average double amplitude of the pressure fluctuation in percent of the dynamic pressure (q).
[3]The frequency of the pressure fluctuation cycles per second.

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Figure 1.- Front view of bomb bay model and net mounted in the 300 MPH 7- by 10-foot tunnel.

Fig. 1

117.05

45.17

38.79

A

1.79

26.55

36.60

A

Pressure
orifices

7.50

25.60

0.60

7.94

12.96

Section A-A
(max. dia.)

9.00

19.35

1.84

80.00

Bomb c.g.

20.36

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Figure 2.- Details of bomb bay model.

Bomb bay A

12.24   36.60   1.79   7.94

Bomb bay B

12.24   18.10   1.79   7.94

Bomb bay C

6.25R.

12.24   18.10   22.10   23°   1.79   7.94

Bomb bay D

6.25R.

12.24   23°   7.94

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Figure 3 .-Details of bomb bay
designs investigated.

Deflector A (solid)
Deflector B (perforated, 25% of area)

3.72
2.70
4.84
a

Deflector C

3.88
3.25
5.13
5.63
a

Deflector D (L=2.70)
Deflector E (L=5.00)

3.72
4.84
L
45°

Pos. of deflectors A, B, & C			a
A-0	B-0	C-0	0
A-3	B-3		3"
A-6	B-6	C-6	6"
A-12	B-12	C-12	12"
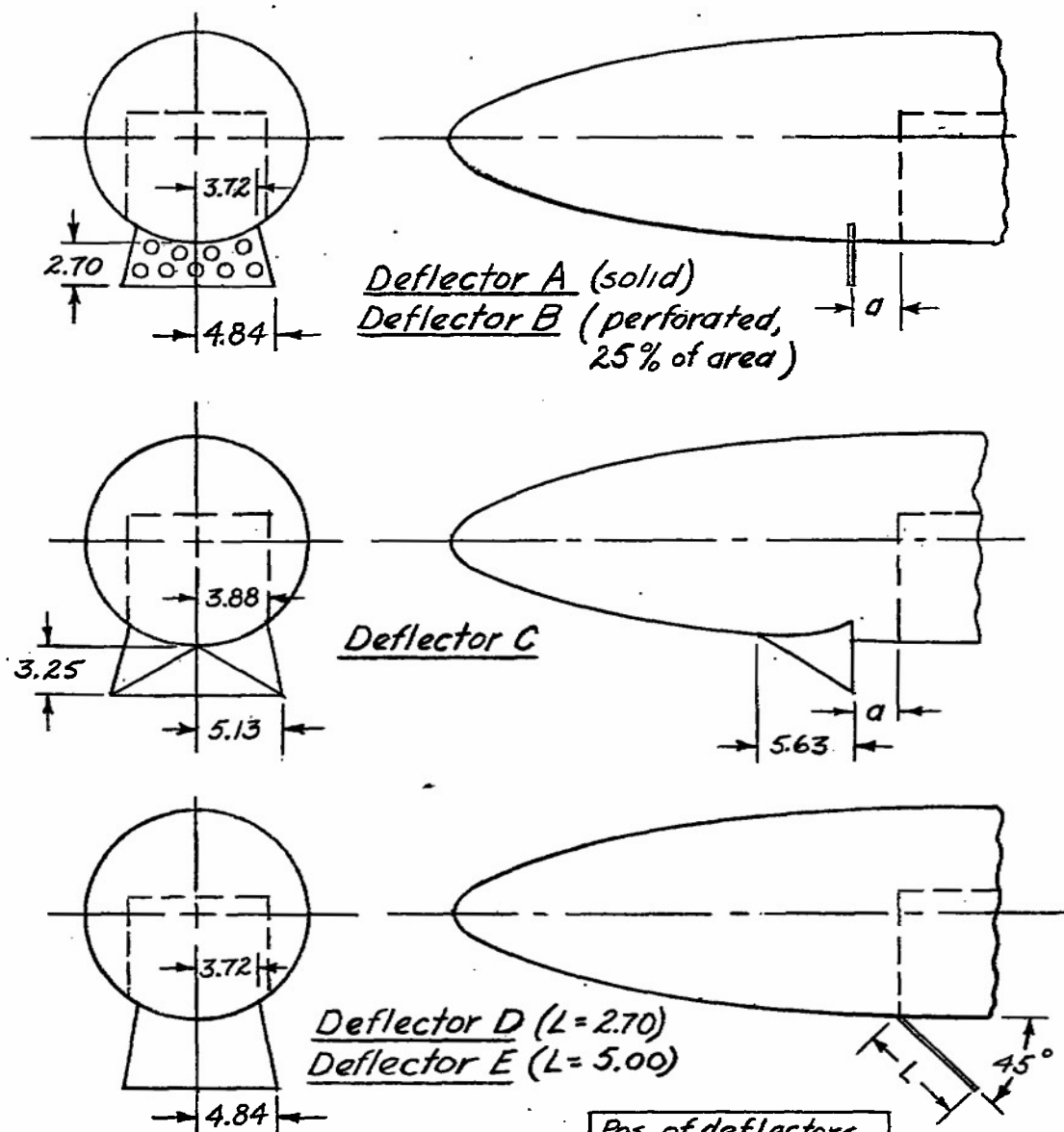
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Figure 4. - Drawing showing details and positions of the
various deflectors tested.

Fig. 5   NACA RM No. L7D11

Front

18.30

36.60

Separator A (solid)
Separator B (perforated, 25% of area)

6.50

Front

6.00

8.00

24.00

8.00

36.60

Separators C (solid)
Separators D (perforated, 25% of area)
Separators E (two front separators perforated,
          " rear   "   solid)
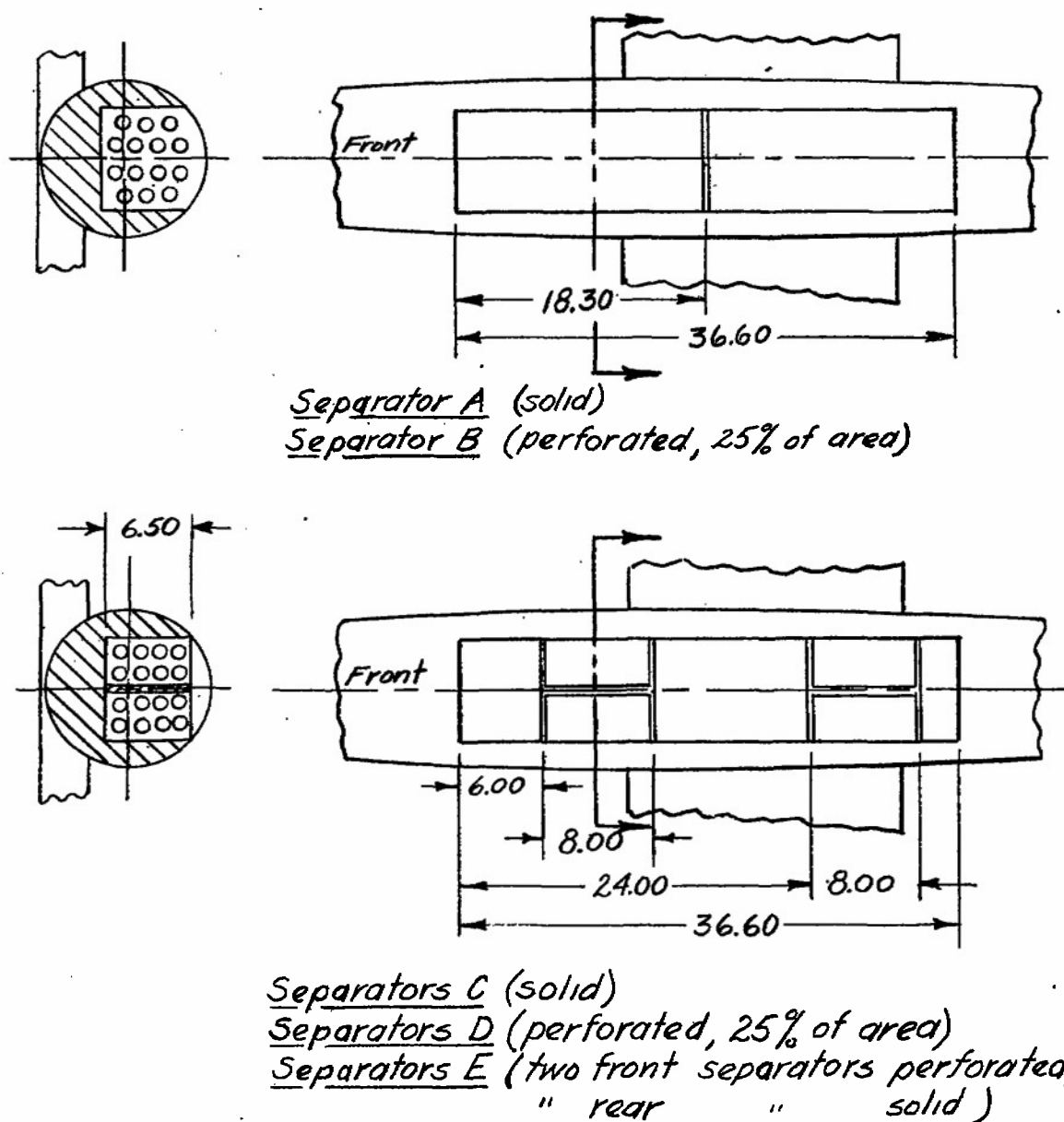
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Figure 5.- Drawing of bomb bay separators.

A&B

4.25

15°   .25

A&B

| Front doors | Rear doors |

18.10

36.60

C

4.25

15°   .25

C

6   18.10

D

4

D

7

16.5
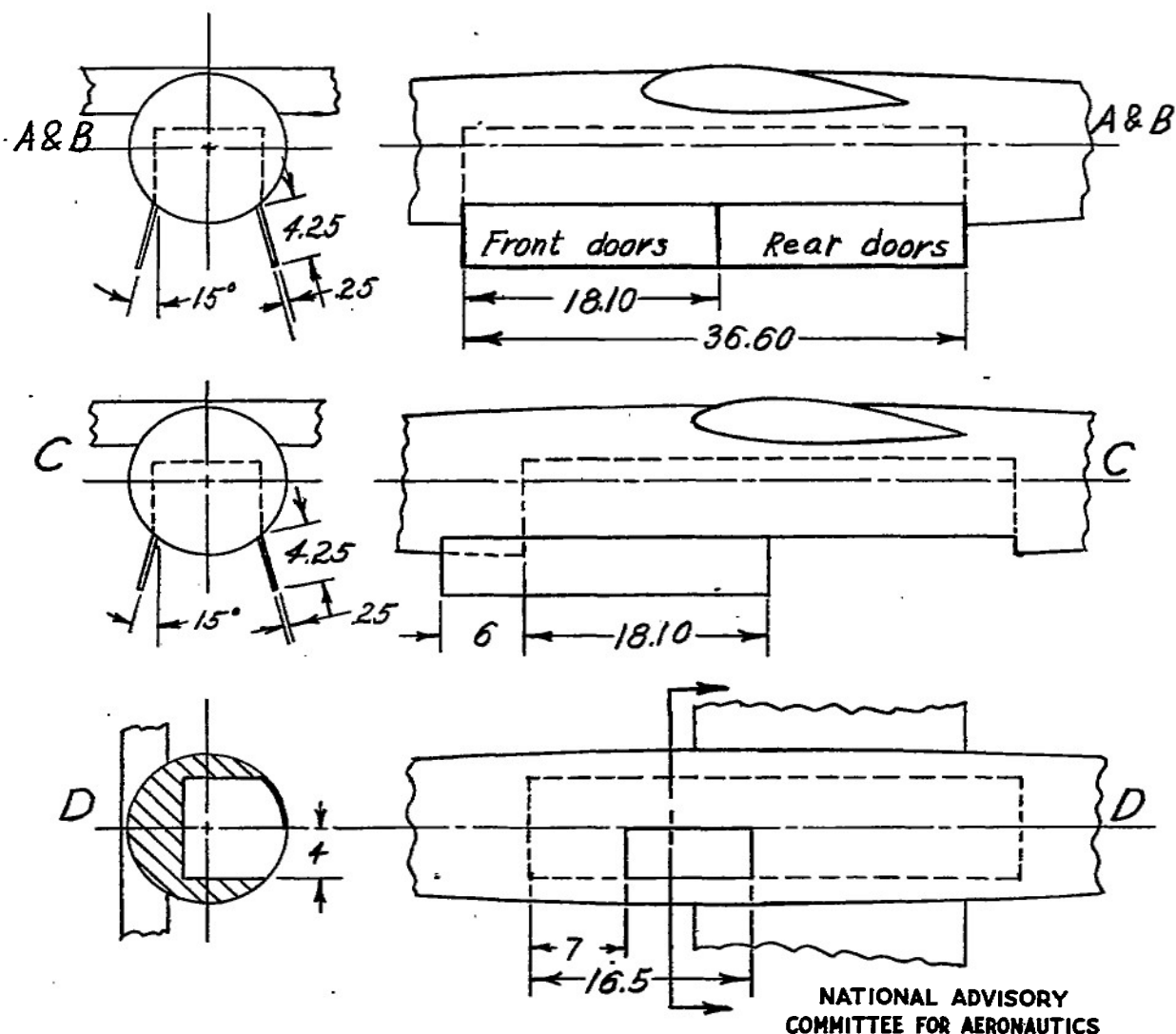
A	Front and Rear Doors
B	Front Doors only
C	Front Doors Extended
D	Small opening in bomb bay

Figure 6 .- Various door arrangements tested.

Fig. 7

Weight : 0.10 lb
Moment of inertia
about lateral axis
0.00313 slug in² (app.)
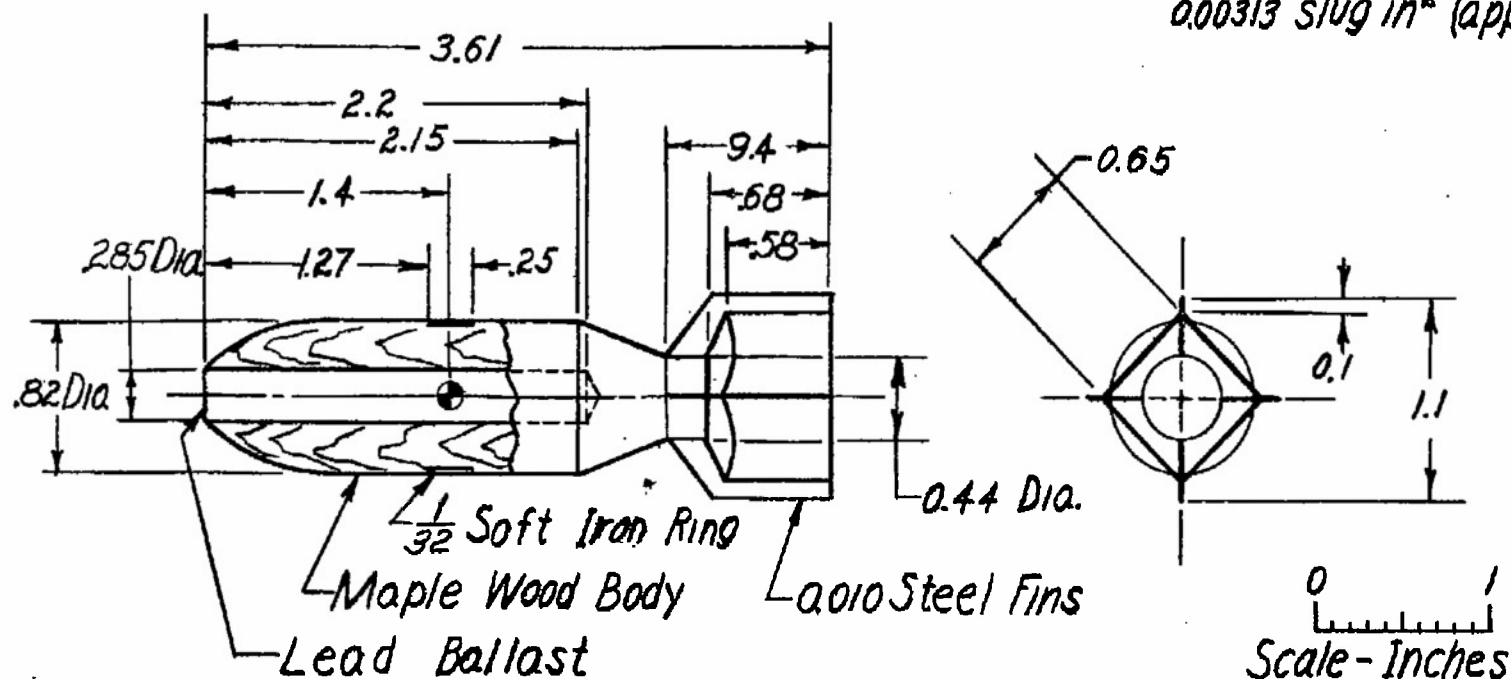
Figure 7 .- Drawing of 0.10 scale model of 100 lb general purpose bomb.

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Figure 8.- View of interior of bomb bay showing magnetic bomb shackles and pressure orifices.

Fig. 8

Configuration 1   Bomb Bay   A

                         Doors   A

Figure 9.-   Representative pictures of drops.

Configuration 1   Bomb Bay   A

                         Doors   A

Tunnel speed reduced to simulate a bombing
speed of 150 mph.

Figure 9.- Continued.
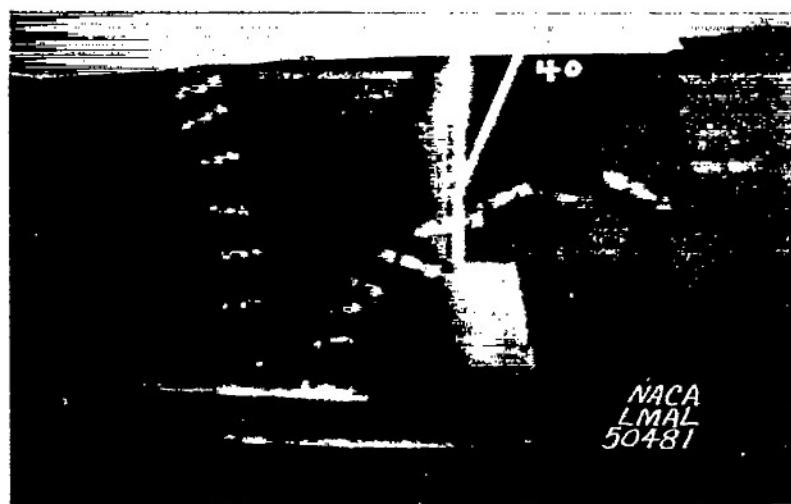
Configuration 3   Bomb Bay   A

                         Doors   D

Figure 9.- Continued.

Configuration 5   Bomb Bay   A

Deflector   C-O

Separator   A

Doors   A

Figure 9.- Continued.

Configuration 11   Bomb Bay   A

Deflector   B-O

Separators   C

Doors   off

Figure 9.- Continued.
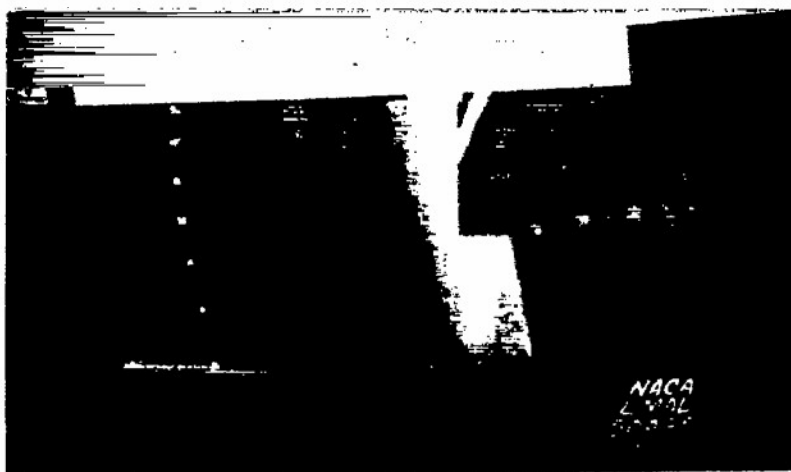
Configuration 20   Bomb Bay   A

                        Deflector   B-3
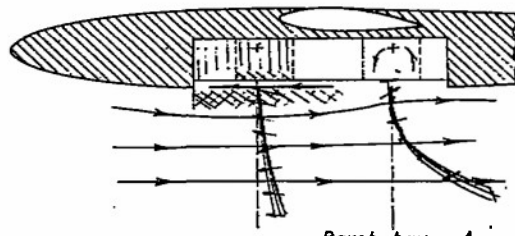
                        Doors   A

                        Spherical bombs
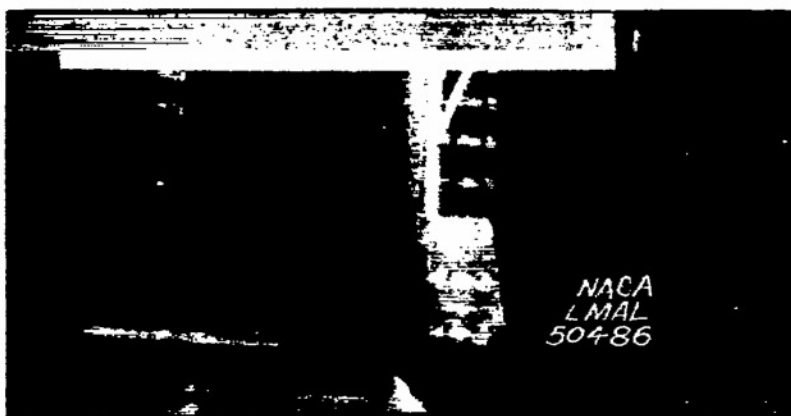
Wind off

Figure 9.- Continued.
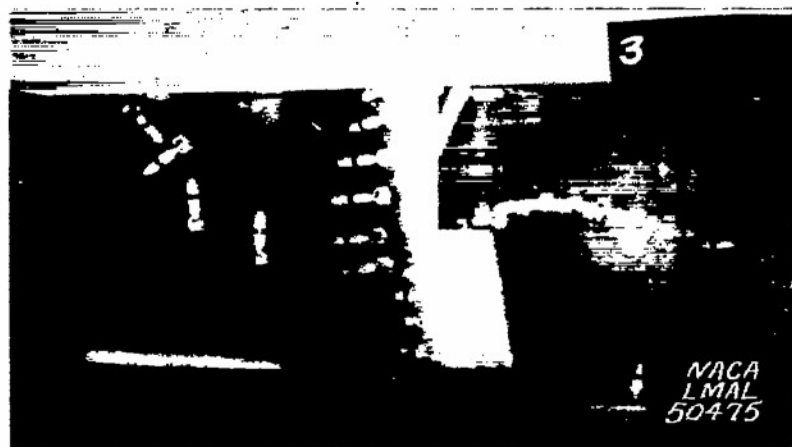
Configuration 24   Bomb Bay   A

                          Deflector   C-O

                          Doors   A

Figure 9.- Continued.
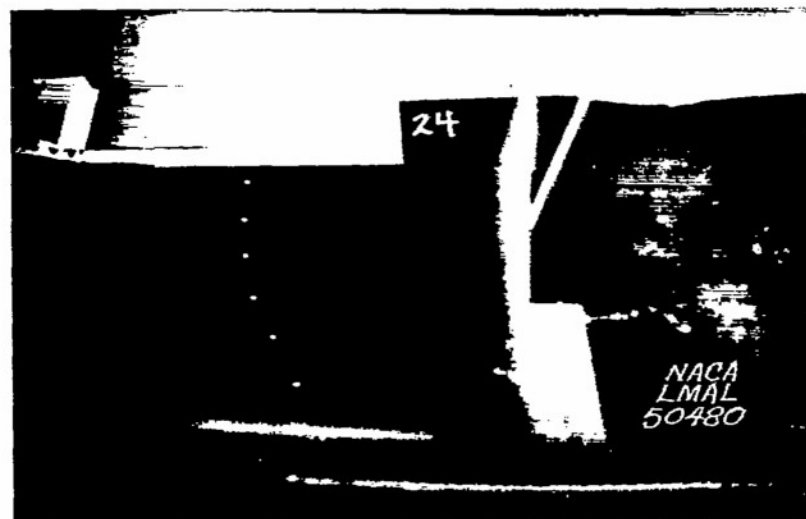
Configuration 35   Bomb Bay   C

                         Deflector   B-6

                         Doors   C

Figure 9.- Concluded.

Dead air —   C.G. of bomb before release —

Turbulence —

Direction of flow —

Vertical line from.
bomb shackle —

Path of bomb

Attitude of bomb

Representative configuration with explanations
of lines and symbols.

Calculated path of bomb. Attitude of bomb
assumed constant at 0° angle of attack.

Configuration 1   Bomb bay A
                          Doors   A

Configuration 1   Bomb bay A
                          Doors   A
              Tunnel speed reduced to simulate
              a bombing speed of 150 M.P.H.

Configuration 1   Bomb bay A
                          Doors   A
       Bomb shackle lowered 3 inches

Configuration £   Bomb bay A
                          Doors   off
       Bomb shackle lowered 3 inches

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Figure 10 .- Results of bomb drops
and tuft studies

Fig. 10 cont.   NACA RM No. L7D11
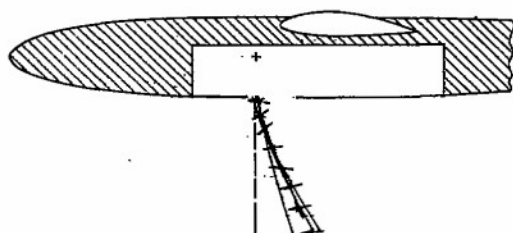
Configuration 3   Bomb bay   A
                        Doors   D
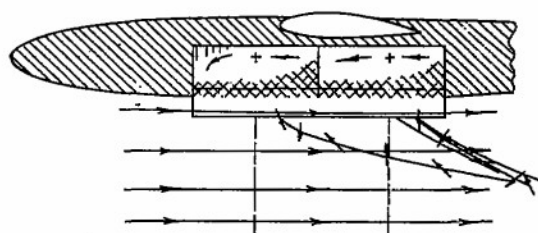
Configuration 4   Bomb bay   A
                        Separators A
                        Doors   A
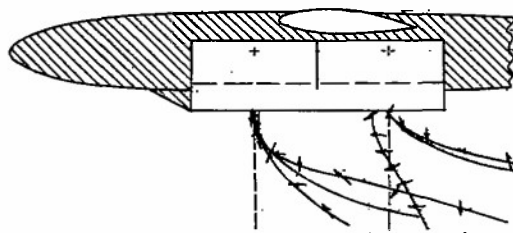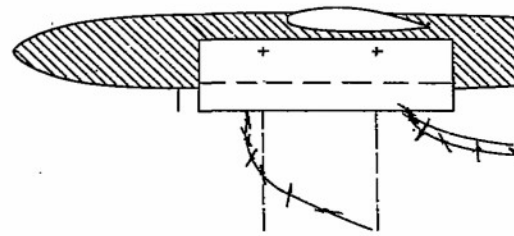
Configuration 5   Bomb bay   A
                        Deflector   C-0
   Separators A
                        Doors   A
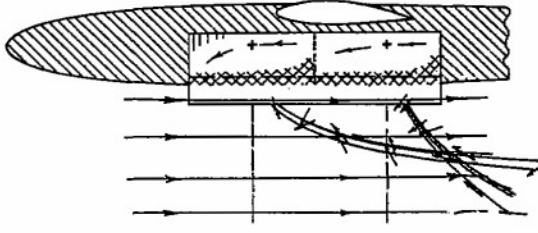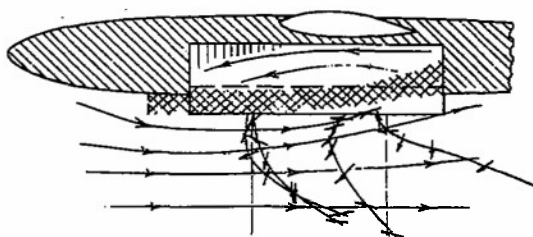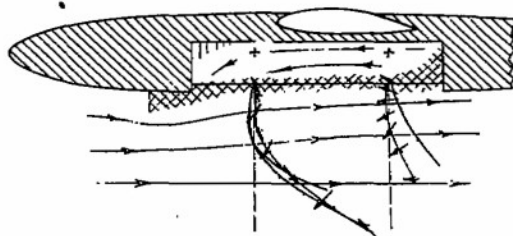
Configuration 6   Bomb bay   A
                        Separators B
                        Doors   A
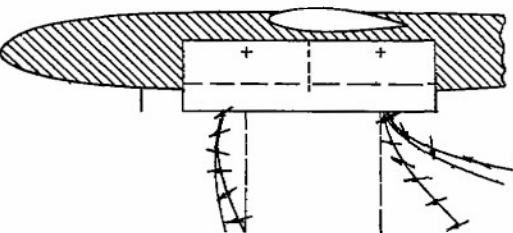
Configuration 7   Bomb bay   A
                        Deflector   A-6
                        Separators B
                        Doors   A
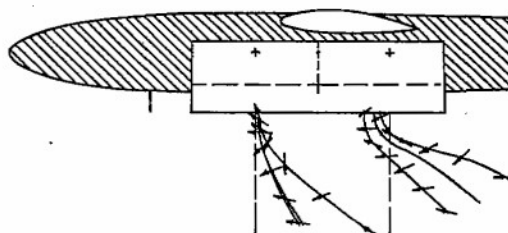
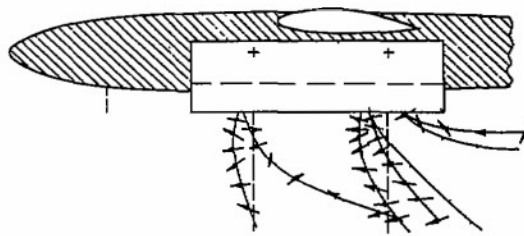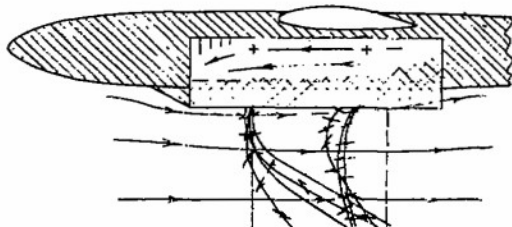Configuration 8   Bomb bay   A
                        Deflector   B-6
                        Separators B
                        Doors   A
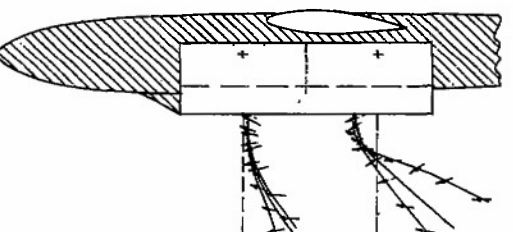
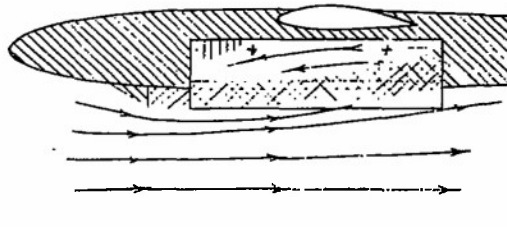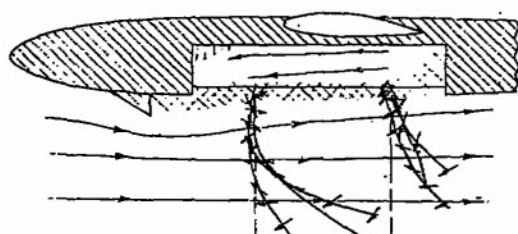Configuration 9   Bomb bay   A
                        Deflector   C-0
                        Separator   B
                        Doors   A
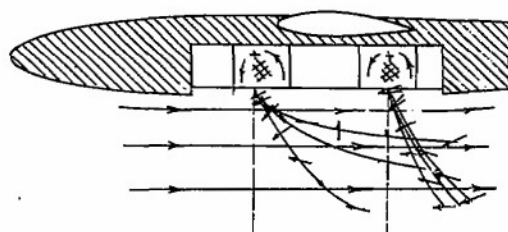
Configuration 10   Bomb bay   A
                        Separators C
                        Doors   off

Figure 10 - Continued

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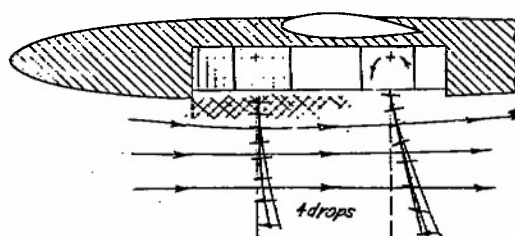
Configuration 11   Bomb bay   A
                     Deflector   B-0
                     Separators C
                     Doors   off

4 drops
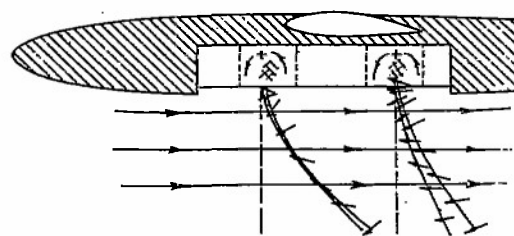
Configuration 12   Bomb bay   A
                     Separators D
                     Doors   off

Configuration 13   Bomb bay   A
                     Deflector   B-0
                     Separators D
                     Doors   off
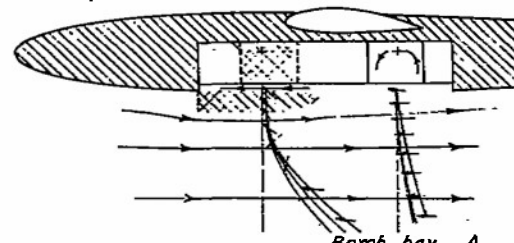
Configuration 14   Bomb bay   A
                     Deflector   B-0
                     Separators E
                     Doors   off
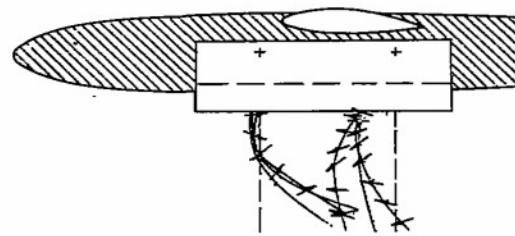
Configuration 15   Bomb bay A
                     Deflector A-0
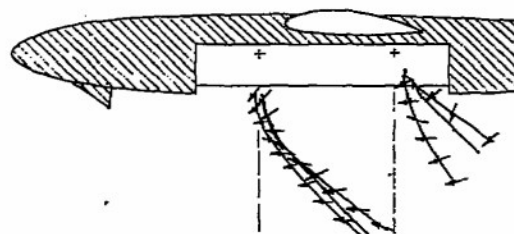   Doors   A

Configuration 16   Bomb bay A
                     Deflector A-3
                     Doors   A
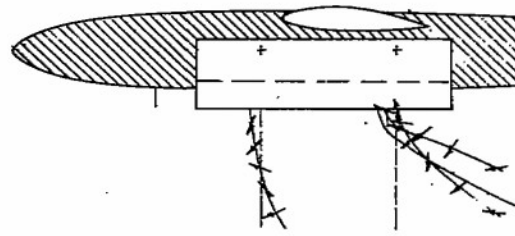
Configuration 17   Bomb bay   A
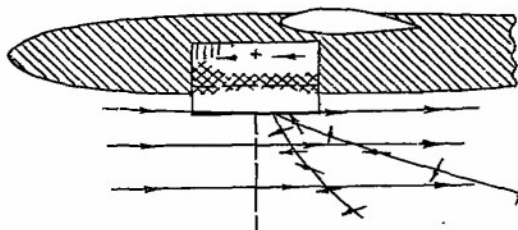   Deflector   A-6
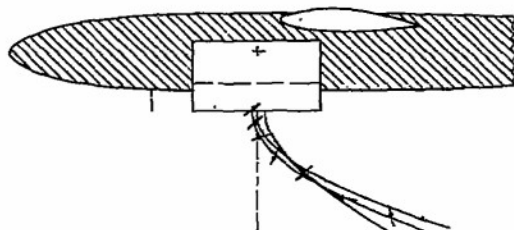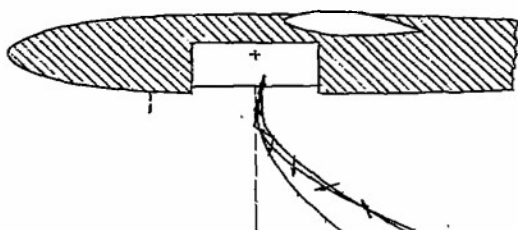   Doors   A
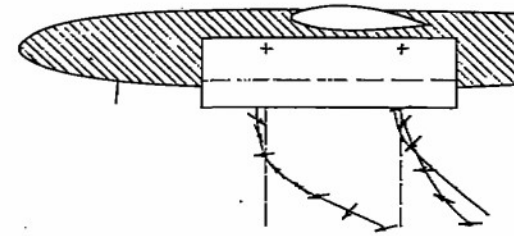
Configuration 18   Bomb bay   A
                     Deflector   A-12
                     Doors   A

Figure 10 .- Continued

Fig. 10 cont.   NACA RM No. L7D11
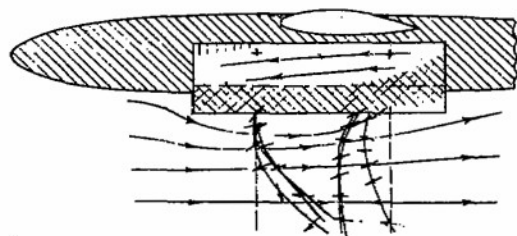
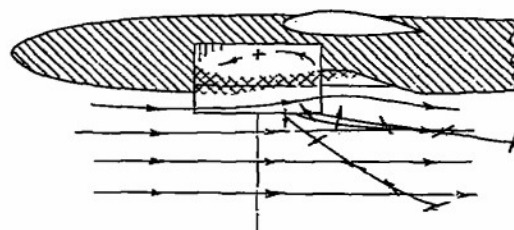Configuration 19   Bomb bay   A
               Deflector   B-0
               Doors   A
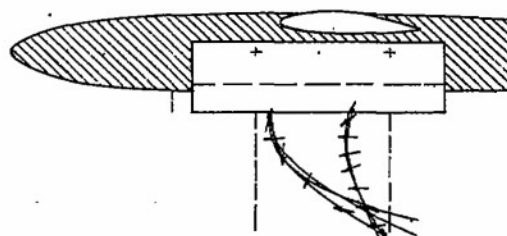
Configuration 20   Bomb bay   A
               Deflector   B-3
               Doors   A
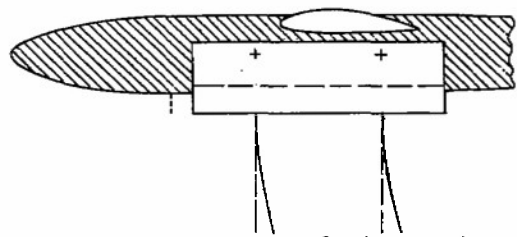
Configuration 20   Bomb bay   A
               Deflector   B-3
               Doors   A
         Spherical bombs

Configuration 21   Bomb bay   A
               Deflector   B-6
               Doors   A

Configuration 22   Bomb bay   A
               Deflector   B-6
               Doors   off

Configuration 23   Bomb bay A
               Deflector B-12
               Doors   A

Configuration 24   Bomb bay   A
               Deflector   C-0
               Doors   A

Configuration 25   Bomb bay   A
               Deflector   C-6
               Doors   A

Figure 10 – Continued

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Configuration 26   Bomb bay   A
                          Deflector C-6
                          Doors   off

Configuration 27   Bomb bay   A
                          Deflector C-12
                          Doors   off

Configuration 28   Bomb bay   B
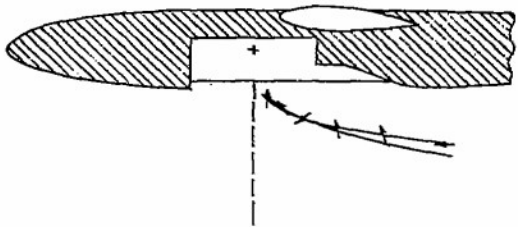   Doors   B

Configuration 29   Bomb bay   B
                          Deflector B-6
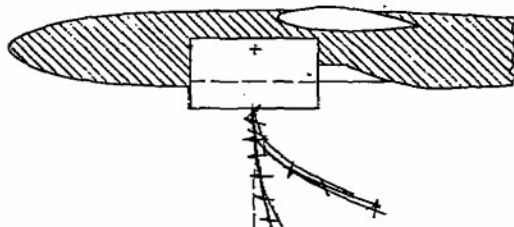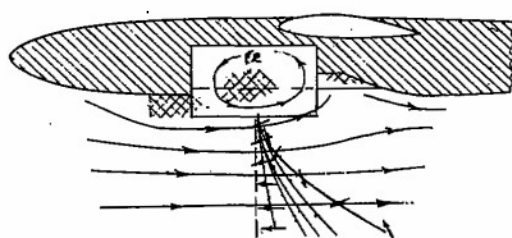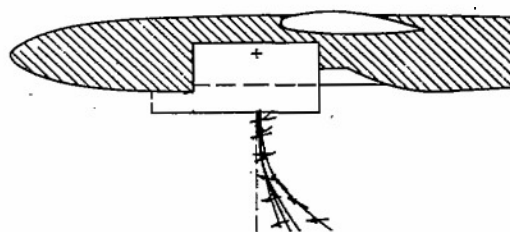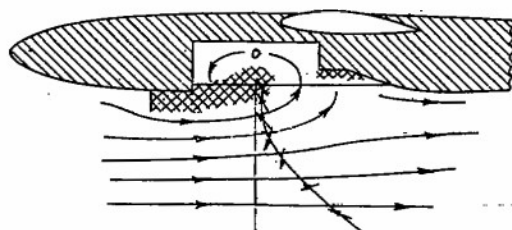   Doors   B

Configuration 30   Bomb bay   B
                          Deflector B-6
                          Doors   -off

Configuration 31   Bomb bay   C
                          Doors   B

Configuration 32   Bomb bay   C
                          Doors   off

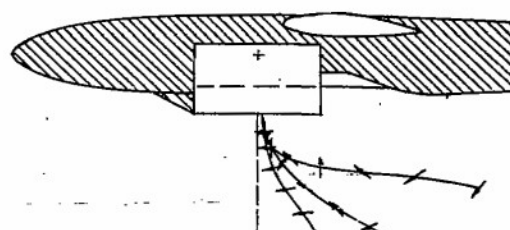Configuration 33   Bomb bay   C
                          Deflector B-0
                          Doors   B

Figure 10 .—Continued

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Fig. 10 cont.   NACA RM No. L7D11

Configuration 34   Bomb bay C
                    Deflector B-6
                    Doors   B

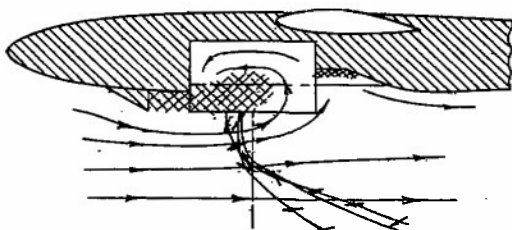Configuration 35   Bomb bay C
                    Deflector B-6
                    Doors   C
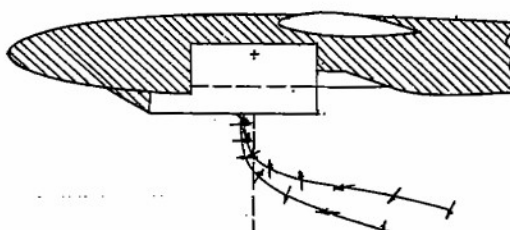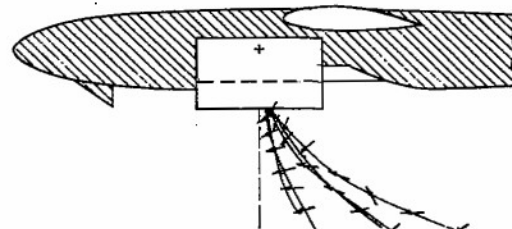
Configuration 36   Bomb bay C
                    Deflector B-6
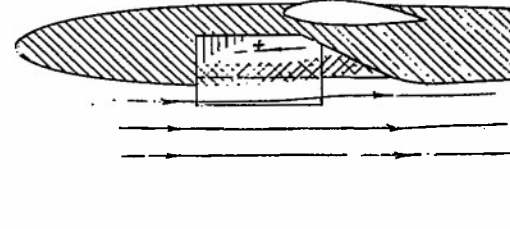   Doors   off

Configuration 37   Bomb bay C
                    Deflector C-0
                    Doors   B

Configuration 38   Bomb bay C
                    Deflector C-6
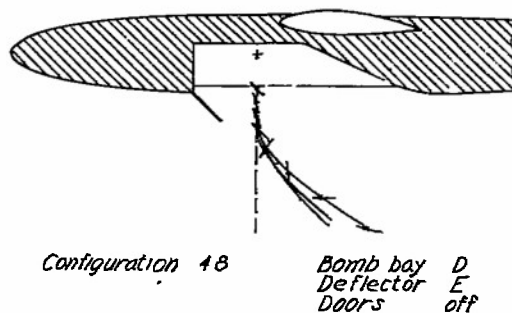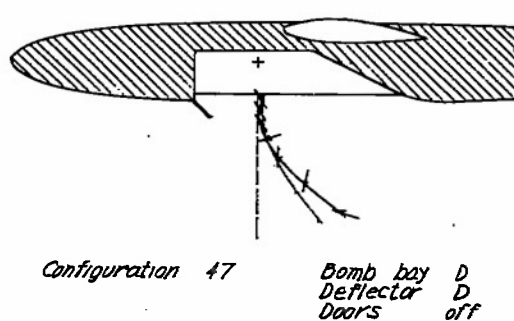   Doors   B

Configuration 39   Bomb bay C
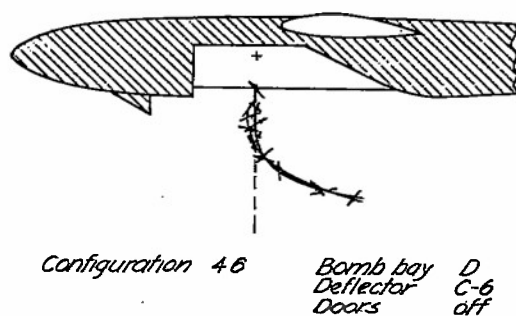   Deflector C-6
                    Doors   C
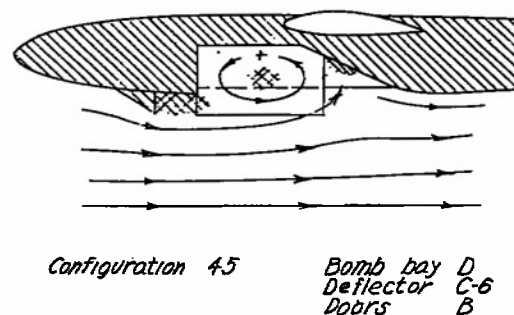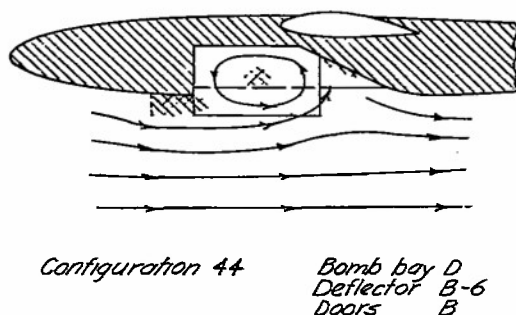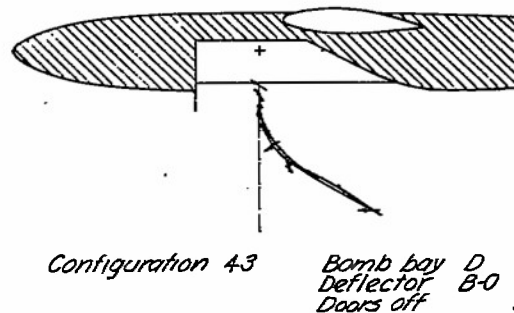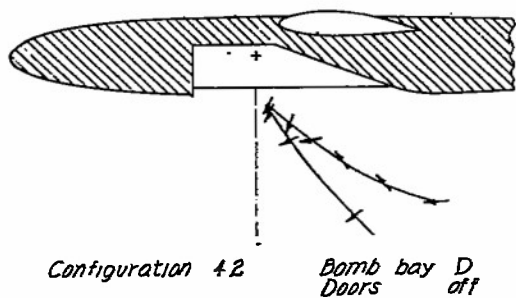
Configuration 40   Bomb bay C
                    Deflector C-12
                    Doors   B

Configuration 41   Bomb bay D
                    Doors   B

Figure 10 .- Continued

Configuration 42   Bomb bay D
                    Doors   off

Configuration 43   Bomb bay D
                    Deflector B-0
                    Doors off

Configuration 44   Bomb bay D
                    Deflector B-6
                    Doors   B

Configuration 45   Bomb bay D
                    Deflector C-6
                    Doors   B

Configuration 46   Bomb bay D
                    Deflector C-6
                    Doors   off

Configuration 47   Bomb bay D
                    Deflector D
                    Doors   off

Configuration 48   Bomb bay D
                    Deflector E
                    Doors   off

Figure 10 .- Concluded

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National Advisory Committee for Aeronautics,
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Va. (L7D11)

I. Kuhn, Richard E.
II. Polhamus, Edward C.

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TUMBLING OF LIGHT-WEIGHT BOMBS (NACA RM),
by Richard E. Kuhn and Edward C. Polhamus.
25 June 1947. 29 pp.   UNCLASSIFIED

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